

NAVAL POSTGRADUATE SCHOOL

Monterey, California



THESIS

"TROPOPLOT"

An Improved Fortran Computer Program for
Prediction of Long-Term Median Tropospheric
Radio Transmission Loss Over Irregular Terrain

by

James Michael Callaghan

Thesis Advisor:

R. W. Adler

June 1973

Thesis
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"TROPCEFLCT"

AN IMPROVED FORTRAN COMPUTER PROGRAM FOR
PREDICTION OF LONG-TERM MEDIAN TROPOSPHERIC
RADIO TRANSMISSION LOSS OVER IRREGULAR TERRAIN

BY

JAMES M. CALLAGHAN LIEUTENANT, UNITED STATES NAVY

SUBMITTED IN PARTIAL FULFILLMENT OF THE
REQUIREMENTS FOR THE DEGREE OF

MASTER OF SCIENCE IN ELECTRICAL ENGINEERING

FROM THE

NAVAL POSTGRADUATE SCHOOL

ABSTRACT

THE OBJECT OF THIS STUDY WAS TO DEVELOP A HIGHLY ACCURATE LONG RANGE COMPUTER PROGRAM TO DO PREDICTIONS OF TROPOSPHERIC RADIO TRANSMISSION LOSS OVER IRREGULAR TERRAIN. THE COMPUTER PROGRAM WAS TO BE EASY TO USE WITH AN INPUT AND OUTPUT DATA FORMAT SUCH THAT THE USER COULD USE THE PROGRAM WITH LITTLE PRIOR INSTRUCTION. SIGNAL STRENGTH CALCULATION CAPABILITY WAS ALSO TO BE INCLUDED IN THE PROGRAM. THE BASIS FOR THE PROGRAM THEORY WAS ESSA RESEARCH REPORT NUMBER ERL 67-ITS 67, "PREDICTION OF TROPOSPHERIC RADIO TRANSMISSION LOSS OVER IRREGULAR TERRAIN."

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I. INTRODUCTION

WHEN RF POWER RADIATES FROM A TRANSMITTING ANTENNA IT IS SPREAD OVER A WIDE AREA. THUS, THE POWER AVAILABLE AT THE RECEIVING ANTENNAS IS ONLY A SMALL PART OF THE RADIATED POWER.

THE LOSS DUE TO TRANSMISSION BETWEEN THE TRANSMITTING AND RECEIVING ANTENNAS DETERMINES IF THE RECEIVED SIGNAL WILL BE USEFUL. POOR QUALITY OR POOR RELIABILITY CAN RESULT IF THE MAXIMUM ALLOWABLE TRANSMISSION LOSS FOR THE RADIO SYSTEM IS EXCEEDED. ON PATHS THAT APPROXIMATE THE IDEAL FREE SPACE OR PLANE EARTH, FAIRLY GOOD PREDICTIONS OF TRANSMISSION LOSS CAN BE MADE. THE ACTUAL PATH GEOMETRY OR ATMOSPHERIC CONDITIONS IN THE REAL WORLD DIFFER SO MUCH FROM THE BASIC ASSUMPTIONS THAT ABSOLUTE ACCURACY CANNOT BE EXPECTED.

THERE IS GREAT INTEREST TODAY IN RADIO WAVE PROPAGATION BEHAVIOR IN THE TROPOSPHERE, WHICH IS THE LAYER OF THE ATMOSPHERE WHERE CLOUDS CAN EXIST. ITS UPPER LIMIT, CALLED THE TROPOPAUSE, IS AT A HEIGHT OF ABOUT SIX KILOMETERS AT THE POLES AND ABOUT EIGHTEEN KILOMETERS AT THE EQUATOR.



MANY COMPLEX FORMULAS HAVE BEEN DERIVED TO MAKE BETTER PREDICTIONS OF TROPOSPHERIC RADIO TRANSMISSION LOSS OVER IRREGULAR TERRAIN. THESE EQUATIONS HAVE BEEN PUT TOGETHER IN ORDER TO ESTABLISH A PROPAGATION THEORY. THE THEORY HAS BEEN TESTED AGAINST A LARGE NUMBER OF PROPAGATION MEASUREMENTS AND HAS HELD UP QUITE WELL. THE MORE ACCURATE THE THEORY THE MORE EQUATIONS NEEDED.

IN THIS DAY AND AGE ACCURATE THEORY REQUIRES A LOT OF TIME TO SOLVE MANY COMPLEX EQUATIONS. A COMPUTER IS NEEDED TO COMBINE THE NUMEROUS EQUATIONS AND SOLVE THEM IN A SHORT AMOUNT OF TIME GIVEN CERTAIN NEEDED INFORMATION. BEFORE A COMPUTER CAN BE USED IT MUST HAVE A SOFTWARE PROGRAM WHICH COMBINES THESE WELL ESTABLISHED EQUATIONS IN AN ORDERLY FASHION IN ORDER TO ARRIVE AT A NUMERICAL SOLUTION.

IN JULY 1968 ESSA RESEARCH LABORATORIES PUBLISHED A TECHNICAL REPORT TITLED: PREDICTION OF TROPOSPHERIC RADIO TRANSMISSION LOSS OVER IRREGULAR TERRAIN--A COMPUTER METHOD-- 1968 BY A. G. LONGLEY AND P. L. RICE. THE REPORT NUMBER WAS ERL 79-ITS 67.

THE ESSA REPORT CONTAINED A COMPUTER METHOD FOR PREDICTING LONG TERM MEDIAN TRANSMISSION LOSS OVER IRREGULAR TERRAIN. THE METHOD WAS APPLICABLE FOR RADIO FREQUENCIES ABOVE 20 MHZ AND MAY BE USED EITHER WITH DETAILED TERRAIN PROFILES FOR ACTUAL PATHS OR WITH PROFILES THAT ARE

REPRESENTATIVE OF MEDIAN TERRAIN CHARACTERISTICS FOR A GIVEN AREA. ESTIMATES OF VARIABILITY IN TIME AND WITH LOCATION AND A METHOD FOR COMPUTING SERVICE PROBABILITY WERE INCLUDED.

THE PROGRAM GIVEN IN THE REPORT WAS VERY LIMITED IN ITS DIRECT APPLICATIONS. IT WAS WRITTEN FOR USE ON A CONTROL DATA CORPORATION COMPUTER, WHICH MADE IT UNUSEABLE FOR AN IBM COMPUTER. THE PROGRAM, AS WRITTEN, COULD NOT READ IN DATA FROM A CARD SOURCE. THE WORK INVOLVED IN THIS THESIS USES NO NEW PROPAGATION THEORY, HOWEVER, IT DOES COMPLETELY REWORK THE SOFTWARE COMPUTER PROGRAM IN THE REPORT IN ORDER TO MAKE IT MORE EASY TO USE, MORE FLEXIBLE AND ACCURATE, AND INCLUDES IN THE OUTPUT, A GRAPHICAL PLOT. IT ALSO RETURNS SIGNAL STRENGTH.

THE PROPAGATION PROGRAM IS INTENDED FOR USE WITHIN THE FOLLOWING RANGES:

PARAMETER	RANGE	
FREQUENCY	20 TO 40,000	MHZ
ANTENNA HEIGHTS	0.5 TO 3,000	M
DISTANCE	1 TO 2,000	KM
SURFACE REFRACTIVITY	250 TO 400	N-UNITS

THE ANGLE OF ELEVATION OF EACH HORIZON RAY ABOVE THE HORIZONTAL SHOULD NOT EXCEED 12 DEGREES, AND THE DISTANCE FROM EACH ANTENNA TO ITS HORIZON SHOULD NOT BE LESS THAN ONE TENTH, OR MORE THAN THREE TIMES, THE CORRESPONDING SMOOTH-EARTH DISTANCE.

II. COMPUTER PROGRAMMED TRANSMISSION THEORY

BEFORE GOING INTO THE PARTICULAR ASPECTS OF HOW TO USE THE PROGRAM, A BRIEF GENERAL OUTLINE OF THE THEORY USED IN THE ERL 79 - ITS 67 REPORT WILL BE GIVEN.

RADIO TRANSMISSION LOSS IN TROPOSPHERIC PROPAGATION DEPENDS ON CHARACTERISTICS OF THE ATMOSPHERE AND TERRAIN. THE REFRACTIVE INDEX GRADIENT NEAR THE EARTH'S SURFACE IS THE MOST IMPORTANT ATMOSPHERIC PARAMETER FOR PREDICTING A LONG TERM MEDIAN REFERENCE VALUE OF TRANSMISSION LOSS. THIS SURFACE GRADIENT LARGELY DETERMINES THE BENDING OF A RADIO RAY AS IT PASSES THROUGH THE ATMOSPHERE. RAYS MAY BE REPRESENTED AS STRAIGHT LINES, WITHIN THE FIRST KILOMETER ABOVE THE EARTH'S SURFACE, IF AN "EFFECTIVE EARTH RADIUS", IS DEFINED AS A REFRACTIVITY.

FOR THE CALCULATION OF THE LONG-TERM REFERENCE VALUE, THE MINIMUM MEAN VALUE IS PICKED TO CHARACTERIZE AVERAGE ATMOSPHERIC CONDITIONS. THE MINIMUM MONTHLY MEAN VALUE OF SURFACE REFRACTIVITY IS OBTAINED FROM MEASUREMENTS FROM SUCH MAPS AS BEAN, HORN, AND CZANICH (1960), "11 CLIMATIC CHARTS AND DATA OF THE RADIO REFRACTIVE INDEX, FOR THE UNITED STATES AND THE WORLD," NBS MONOGRAPH NO. 22 (U.S. GOVERNMENT

PRINTING OFFICE, WASHINGTON, D. C.)

ATMOSPHERIC EFFECTS, SUCH AS CHANGES IN THE REFRACTIVE INDEX, CHANGES IN THE AMOUNT OF TURBULENCE OR STRATIFICATION, ABSORPTION BY OXYGEN, WATER VAPOR, CLOUDS, AND PRECIPITATION, ARE ALLOWED FOR BY EMPIRICAL ADJUSTMENTS.

PROGRAM CALCULATIONS ARE INCLUDED TO HANDLE EFFECTS OF TROPOSPHERIC SCATTER AND DIFFRACTION DUE TO KNIFE EDGES, ROUGH TERRAIN, AND SMOOTH SPHERICAL EARTH. SHORT AND LONG TERM FADING ADJUSTMENTS TO MEDIAN ATTENUATIONS ARE ACCOUNTED FOR BY DERIVING FACTORS WHICH COME FROM AVERAGING FADING MEASUREMENTS MADE ON MANY DIFFERENT TROPOSPHERIC COMMUNICATIONS SYSTEMS.

IF DETAILED PROFILES ARE AVAILABLE FOR SPECIFIC PATHS, TRANSMISSION LOSS CAN BE CALCULATED. TO CHARACTERIZE TERRAIN, PROFILES MAY BE READ AT REGULAR INTERVALS IN BOTH N-S AND E-W DIRECTIONS OR ACTUAL OR PROPOSED TERRAIN CONDITIONS MAY BE COMBINED TO PROVIDE A SINGLE SET OF PROFILES FOR WHICH AN ESTIMATE OF MEDIAN PROPAGATION CONDITIONS IS DESIRED. THE INTERDECILE RANGE OF TERRAIN HEIGHTS ABOVE AND BELOW A FIXED LINE FITTED TO ELEVATIONS ABOVE SEA LEVEL, IS CALCULATED AT FIXED DISTANCES. USUALLY MEDIAN VALUES OF THE INTERDECILE RANGE INCREASE WITH PATH LENGTH TO AN ASYMPTOTIC VALUE WHICH IS USED TO CHARACTERIZE THE TERRAIN.

TYPE OF TERRAIN	ASYMPTOTIC VALUE (METERS) OF INTERDECILE HEIGHT
VERY SMOOTH PLAINS OR WATER	0-5
SMOOTH PLAINS	5-20
SLIGHTLY ROLLING PLAINS	20-40
ROLLING PLAINS	40-80
HILLS	80-150
MOUNTAINS	150-300
RUGGED MOUNTAINS	300-700
EXTREMELY RUGGED MOUNTAINS	> 700

TO CALCULATE REFERENCE VALUES OF TRANSMISSION LOSS FOR A SPECIFIC APPLICATION, A MINIMUM OF FOUR ESSENTIAL PARAMETERS MUST BE SUPPLIED. THESE FOUR PARAMETERS ARE FREQUENCY IN MEGAHERTZ, THE TRANSMITTING AND RECEIVING ANTENNA HEIGHTS ABOVE GROUND IN METERS, AND THE PATH DISTANCE IN KILOMETERS. PATH PARAMETERS SUCH AS HORIZON DISTANCES AND ELEVATION ANGLES, MAY ALSO BE DERIVED FROM THE PRECEDING PARAMETERS.

THE CONDUCTIVITY OF THE EARTH'S SURFACE AND ITS

PERMITTIVITY OR RELATIVE DIELECTRIC CONSTANT ENTER INTO THE CALCULATIONS FOR LINE-OF-SIGHT AND DIFFRACTION ATTENUATION. IF THE VALUES OF THESE GROUND CONSTANTS ARE NOT KNOWN, THE FOLLOWING TABLE VALUES MAY BE ASSUMED:

TYPE OF SURFACE	CONDUCTIVITY(MHO/M)	DIELECTRIC CONSTANT
POOR GROUND	0.001	4
AVERAGE GROUND	0.005	15
GOOD GROUND	0.020	25
SEA WATER	5.000	81
FRESH WATER	0.010	81

AT SUFFICIENTLY LOW FREQUENCIES, THE EFFECT OF THE CONDUCTIVITY DOMINATES WHILE AT SUFFICIENTLY HIGH FREQUENCIES, THE DIELECTRIC CONSTANT DOMINATES. THE TRANSITION OCCURS BETWEEN 300 TO 3000 MEGAHERTZ FOR OVERSEA TRANSMISSION, WHILE OVER "AVERAGE" GROUND THE TRANSITION OCCURS BETWEEN 5 TO 50 MEGAHERTZ. FOR PROPAGATION OVER IRREGULAR TERRAIN, AT FREQUENCIES ABOVE 100 MEGAHERTZ, WITH ANTENNAS MORE THAN FIVE METERS ABOVE GROUND, THE EFFECTS OF THE GROUND CONSTANTS ARE SLIGHT AND THE RESULT, FOR VERTICAL AND HORIZONTAL POLARIZATION IS NEARLY THE SAME. UNDER THESE

CONDITIONS THE METHOD IS SIMPLIFIED BY ASSUMING THE MAGNITUDE OF THE THEORETICAL REFLECTION COEFFICIENT EQUAL TO 0.95 AND THE PHASE SHIFT EQUAL TO ZERO. FOR MANY APPLICATIONS THIS RESULTS IN AN ESTIMATE OF THE EFFECTIVE REFLECTION COEFFICIENT OF 0.9, AND THE ATTENUATION MAY BE CALCULATED DIRECTLY. THESE APPROXIMATIONS ARE NOT APPLICABLE FOR TRANSMISSION OVER THE SEA.

TO SUMMARIZE, THE PARAMETERS REQUIRED FOR COMPUTING REFERENCE VALUES OF TRANSMISSION, OR THE CORRESPONDING ATTENUATION BELOW FREE SPACE ARE: FREQUENCY IN MEGAHERTZ, DISTANCE IN KILOMETERS, ANTENNA HEIGHTS ABOVE GROUND IN METERS, ESTIMATES OF SURFACE REFRACTIVITY, THE TERRAIN IRREGULARITY IN METERS, THE CONDUCTIVITY IN MHCS/METER, AND THE RELATIVE DIELECTRIC CONSTANT OF THE GROUND.

III. USING THE MODIFIED ERL PROGRAM

THE MODIFIED ERL COMPUTER PROGRAM WAS WRITTEN FOR EASE OF OUTPUT READING, ACCURACY, AND EASE OF USER DATA INPUT. THE PROGRAM LISTING CONTAINS INSTRUCTIONS FOR DATA INPUT. THIS ALLOWS THE PROGRAM TO BE USED WITHOUT EXTERNAL PROGRAM INSTRUCTIONS.

THERE ARE ONLY FOUR DATA INPUT CARDS USED IN THIS PROGRAM. IN MANY CASES ONLY TWO DATA INPUT CARDS ARE USED. THIS PROGRAM PREDICTS LONG-TERM MEDIAN RADIO TRANSMISSION LOSS OVER IRREGULAR TERRAIN. THUS, THE USER SHOULD NOT EXPECT A SHORT TERM LOSS PREDICTION OUTPUT EVEN THOUGH THE INPUT DATA IS OF A SHORT TERM NATURE.

INTEGER NUMBERS MUST BE PUNCHED SO THAT THE NUMBER ENDS IN THE LAST COLUMN NUMBER FIELD. IF SPACES ARE LEFT AT THE END OF THE FIELD THEY WILL BE READ AS ZEROS, IN EFFECT MULTIPLYING THE DESIRED NUMBER BY A POWER OF TEN. REAL NUMBERS ARE PUNCHED AS A STRING OF DIGITS CONTAINING A DECIMAL, AND MAY BE PUNCHED ANYWHERE IN THEIR FIELD.

FIRST DATA CARD:

THE FIRST DATA CARD CONTAINS DATA COVERING CODE NUMBERS FOR TYPE OF TERRAIN, DB LOSS INFORMATION DESIRED, AND DISTANCE BETWEEN ANTENNAS. THIS CARD MUST BE INCLUDED IN THE DATA CARD SET.

COLUMN: 01-10 "TYPE OF TERRAIN" -INTEGER

CODE: 1	COLORADO PLAINS (OMIT THIRD DATA CARD)
CODE: 2	COLORADO MOUNTAINS (OMIT THIRD DATA CARD)
CODE: 3	OHIO (OMIT THIRD DATA CARD)
CODE: 4	USER TERRAIN DATA WITHOUT DATA SUPPRESSION
CODE: 5	USER TERRAIN DATA NO "OUTPUT PARAMETERS" PRINTED

COLUMN: 11-20 "DB LOSS" -INTEGER

CODE: 0	NO DB DATA DESIRED (OMIT SECOND DATA CARD)
CODE: 1	DB DATA DESIRED

COLUMN: 21-30 "DISTANCE BETWEEN ANTENNAS" -REAL
(1-2,000) K-METERS

SECOND DATA CARD:

THE SECOND DATA CARD CONTAINS DATA COVERING SIGNAL STRENGTH DB CALCULATIONS AND OUTPUT. IF COLUMN 11-20 OF THE FIRST DATA CARD CONTAINS A "0" THE SECOND DATA CARD IS OMITTED.

COLUMN: 01-10 "TX POWER OUT" (WATTS)
POSITIVE REAL NUMBER

COLUMN: 11-20 "TX ANTENNA GAIN" (DB)
POSITIVE REAL NUMBER

COLUMN: 21-30 "RX ANTENNA GAIN" (DB)
POSITIVE REAL NUMBER

COLUMN: 31-40 "TRANSMITTER LINE LOSS" (DB)
 POSITIVE REAL NUMBER
 COLUMN: 41-50 "REQUIRED RECEIVER LINE LOSS" (DB)
 POSITIVE REAL NUMBER
 COLUMN: 51-60 "RECEIVER INPUT LEVEL" (DBM)
 POSITIVE REAL NUMBER

THIRD DATA CARD:

THE THIRD DATA CARD CONTAINS DATA COVERING SURFACE REFRACTIVITY, SURFACE CONDUCTIVITY, PERMITTIVITY OR RELATIVE DIELECTRIC CONSTANT, AND INTERDECILE RANGE. THIS CARD IS NOT USED IF COLUMN 01-10 OF THE FIRST DATA CARD CONTAINS A "1", "2", OR "3".

COLUMN: 01-10 "SURFACE REFRACTIVITY" -INTEGER
 (250-400) N-UNITS NS
 COLUMN: 11-20 "SURFACE CONDUCTIVITY" (MHCS/METER)
 COLUMN: 21-30 "PERMITTIVITY OR RELATIVE DIELECTRIC
 CONSTANT"
 COLUMN: 31-40 "INTERDECILE RANGE"
 DELTA-H

FORTH DATA CARD:

THE FORTH DATA CARD CONTAINS DATA COVERING ANTENNA POLARIZATION, FREQUENCY, AND ANTENNA HEIGHT OF THE TRANSMITTING AND RECEIVING ANTENNA. THIS CARD MUST BE INCLUDED IN THE DATA CARD SET.

COLUMN: 01-10 "ANTENNA POLARIZATION" -REAL
 CODE: 01.00 VERTICAL POLARIZATION
 CODE: -1.00 HORIZONTAL POLARIZATION
 COLUMN: 11-20 "FREQUENCY" (MEGAHERTZ)
 (20-40,000)
 COLUMN: 21-30 "STRUCTURAL ANTENNA HEIGHT OF
 TRANSMITTING ANTENNA" -REAL
 (0.5-3000.0) METERS
 COLUMN: 31-40 "STRUCTURAL ANTENNA HEIGHT OF
 RECEIVING ANTENNA" -REAL
 (0.5-3000.0) METERS

DATA CARD ONE CONTAINS CODES FOR THE USE OF COLORADO PLAINS, COLORADO MOUNTAINS, OR OHIO TERRAIN PARAMETERS. THESE PARAMETER OPTIONS WERE PUT IN THE PROGRAM SINCE THEY OFFER WELL-USED GENERAL TYPES OF DIFFERING TERRAIN. FOR EXAMPLE, IF THE USER DOES NOT HAVE ANY PARTICULAR TERRAIN CONSTANTS TO USE AND WANTED TO CHECK HIS DATA USING A MOUNTAINOUS TERRAIN, HE WOULD USE THE CODE IN THE FIRST DATA CARD FOR COLORADO MOUNTAIN TERRAIN. THE FOLLOWING TABLE GIVES THE CONSTANTS USED IN THE PROGRAM FOR THE PRESET TERRAINS:

TERRAIN	SURFACE REFRACTIVITY	SURFACE CONDUCTIVITY	DIELECTRIC CONSTANT	DH DELTA-H
OHIO	312.0	0.005	15.0	90.0
COLORADO PL.	290.0	0.005	15.0	90.0
COLORADO MT.	290.0	0.005	15.0	650.0

EXAMPLE PROGRAM DATA CARD SETUP

THE FOLLOWING TWO EXAMPLES SHOULD GIVE THE USER A BETTER GRASP OF SETTING UP THE DATA CARDS FOR THE MODIFIED ERL PROGRAM.

EXAMPLE ONE:

THE USER WANTS TO USE COLORADO PLAINS TYPE TERRAIN DATA. HE ALSO WANTS TO USE THE FOLLOWING DATA:

DB LCSS -----	YES
FREQUENCY -----	450.00 MEG-HERTZ
TX POWER OUT -----	8.00 WATTS
TX ANTENNA GAIN -----	10.00 DB
RX ANTENNA GAIN -----	13.50 DB
RECEIVER LINE LOSS -----	2.00 DB
ANTENNA POLARIZATION -----	VERTICAL
TRANSMISSION LINE LCSS -----	2.00 DB
DISTANCE BETWEEN ANTENNAS -----	242.0 K-METERS
REQUIRED RECEIVER INPUT LEVEL -----	-113.00 DBM
STRUCTURAL ANTENNA HEIGHT OF TX ANTENNA	4.00 METERS
STRUCTURAL ANTENNA HEIGHT OF RX ANTENNA	40.00 METERS

EXAMPLE TWO:

THE USER WANTS TO USE HIS OWN TERRAIN DATA AND DOES NOT WANT TO USE THE SIGNAL STRENGTH PROGRAM OPTION. THE USER DESIRES TO USE THE FOLLOWING DATA:

DB LOSS -----	NC
DELTA-H -----	750.00 METERS
FREQUENCY -----	100.00 MEG-HERTZ
DIELECTRIC CONSTANT -----	15.00
ANTENNA POLARIZATION -----	HORIZONTAL
SURFACE CONDUCTIVITY -----	0.005 M-MS/METER
SURFACE REFRACTIVITY -----	350.00 N-UNITS
DISTANCE BETWEEN ANTENNAS -----	300.00 K-METERS
STRUCTURAL ANTENNA HEIGHT OF TX ANTENNA	37.05 METERS
STRUCTURAL ANTENNA HEIGHT OF RX ANTENNA	72.08 METERS

TABLE OF THE EXAMPLE DATA CARD SETTINGS

CARDS AND COLUMNS	EXAMPLE ONE	EXAMPLE TWO
FIRST DATA CARD		
01-10	1	4
11-20	1	0
21-30	242.0	300.00
SECOND DATA CARD		(NOT USED)
01-10	8.0	-----
11-20	10.0	-----
21-30	13.5	-----
31-40	2.0	-----
41-50	2.0	-----
51-60	113.0	-----
THIRD DATA CARD		(NOT USED)
01-10	-----	350.00
11-20	-----	0.005
21-30	-----	15.00
31-40	-----	750.00
FOURTH DATA CARD		
01-10	1.0	-1.0
11-20	450.0	100.00
21-30	4.0	37.05
31-40	40.0	72.08

NOTE: ALL INTEGER VALLES MUST BE RIGHT JUSTIFIED IN THEIR RESPECTIVE COLUMNS FIELDS.

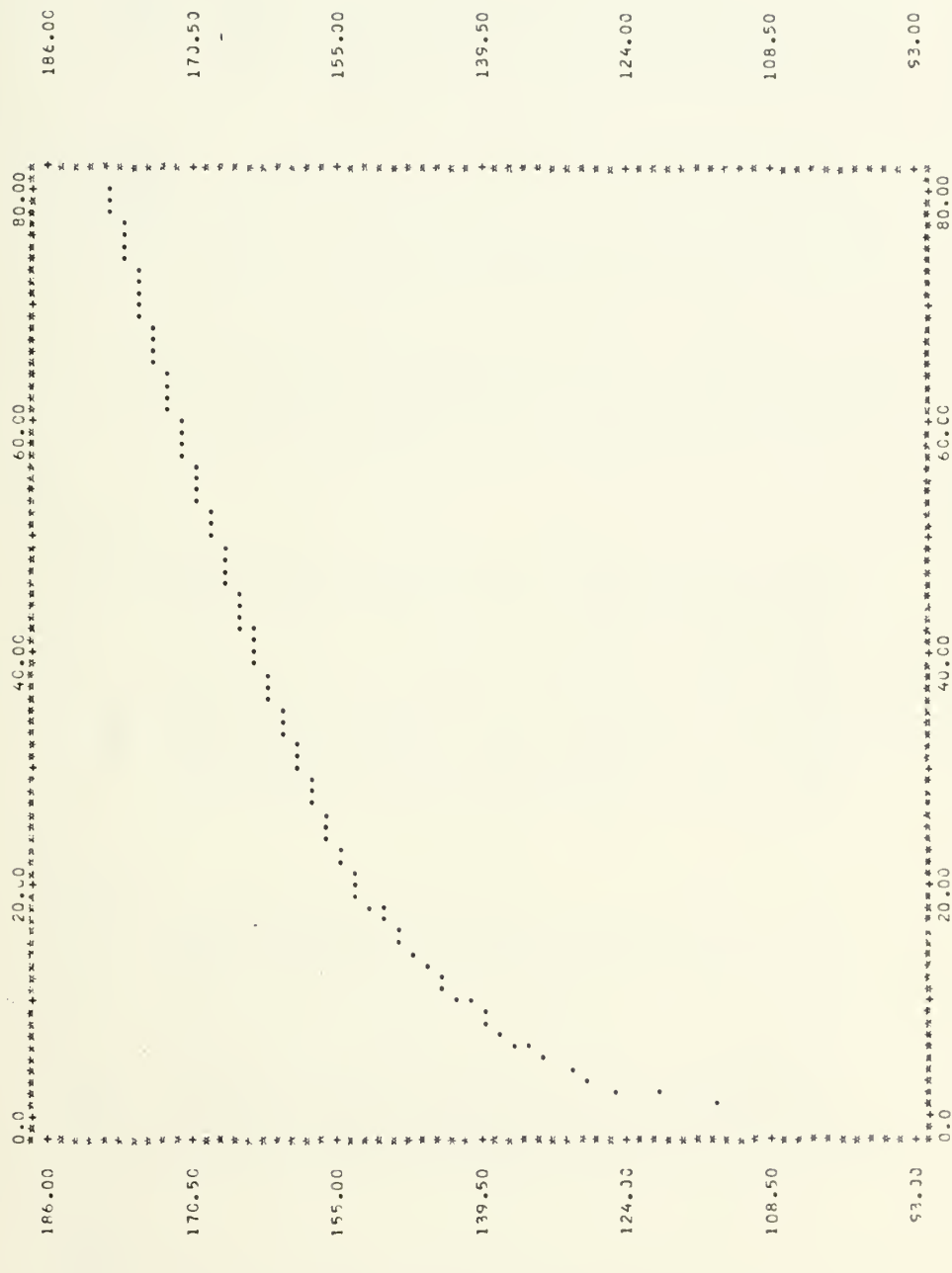
THE NEXT SECTION, STARTING ON PAGE 19, CONTAINS THE SAMPLE OUTPUT DATA FORMATS. THE PROGRAM LISTING STARTS ON PAGE 23.

FREQUENCY OF SIGNAL - F- (MEG-HERTZ) : 100.00000

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PLOT OF TRANS.-LCSS VERSUS DISTANCE

** NOTE ** TO FIND SIGNAL STRENGTH FROM GRAPH, SUBTRACT TRANS.-LCSS FROM 66.00



TRANS-LCSS (DB)

DISTANCE (K-METERS)

--- SIGNAL STRENGTH VERSUS DISTANCE FOR GIVEN SYSTEM PARAMETERS ---

DISTANCE (KM)	SIG-STRENGTH (DBM)	DISTANCE (KM)	SIG-STRENGTH (DBM)	DISTANCE (KM)	SIG-STRENGTH (DBM)	DISTANCE (KM)	SIG-STRENGTH (DBM)	DISTANCE (KM)	SIG-STRENGTH (DBM)
0.8000----	-48.41	16.8000----	-84.25	32.8000----	-94.75	48.8000----	-102.12	64.8000----	-108.50
1.6000----	-55.11	17.6000----	-85.09	33.6000----	-95.16	49.6000----	-102.46	65.6000----	-108.80
2.4000----	-59.19	18.4000----	-85.90	34.4000----	-95.56	50.4000----	-102.79	66.4000----	-109.10
3.2000----	-62.21	19.2000----	-86.70	35.2000----	-95.95	51.2000----	-103.13	67.2000----	-109.40
4.0000----	-64.65	20.0000----	-87.32	36.0000----	-96.34	52.0000----	-103.46	68.0000----	-109.70
4.8000----	-66.71	20.8000----	-87.86	36.8000----	-96.73	52.8000----	-103.78	68.8000----	-110.00
5.6000----	-68.52	21.6000----	-88.38	37.6000----	-97.11	53.6000----	-104.11	69.6000----	-110.30
6.4000----	-70.15	22.4000----	-88.89	38.4000----	-97.49	54.4000----	-104.44	70.4000----	-110.59
7.2000----	-71.63	23.2000----	-89.39	39.2000----	-97.87	55.2000----	-104.76	71.2000----	-110.89
8.0000----	-72.95	24.0000----	-89.88	40.0000----	-98.24	56.0000----	-105.08	72.0000----	-111.18
8.8000----	-74.27	24.8000----	-90.36	40.8000----	-98.61	56.8000----	-105.40	72.8000----	-111.47
9.6000----	-75.47	25.6000----	-90.84	41.6000----	-98.97	57.6000----	-105.72	73.6000----	-111.76
10.4000----	-76.61	26.4000----	-91.30	42.4000----	-99.33	58.4000----	-106.03	74.4000----	-112.05
11.2000----	-77.69	27.2000----	-91.75	43.2000----	-99.69	59.2000----	-106.34	75.2000----	-112.34
12.0000----	-78.73	28.0000----	-92.20	44.0000----	-100.05	60.0000----	-106.66	76.0000----	-112.63
12.8000----	-79.73	28.8000----	-92.64	44.8000----	-100.40	60.8000----	-106.97	76.8000----	-112.91
13.6000----	-80.69	29.6000----	-93.08	45.6000----	-100.75	61.6000----	-107.28	77.6000----	-113.20
14.4000----	-81.62	30.4000----	-93.50	46.4000----	-101.09	62.4000----	-107.59	78.4000----	-113.49
15.2000----	-82.52	31.2000----	-93.93	47.2000----	-101.44	63.2000----	-107.89	79.2000----	-113.77
16.0000----	-83.40	32.0000----	-94.34	48.0000----	-101.78	64.0000----	-108.20	80.0000----	-114.05

***** FOR A RECEIVER INPUT LEVEL OF -90.00 DBM. DISTANCE BETWEEN ANTENNAS CAN BE AT LEAST 24.00 KM *****

--- PROGRAM PARAMETERS ---

POLARIZATION (POL) ----- VERTICAL
 FREQUENCY OF SIGNAL (F) ----- 100.00 MEG-HERTZ
 SURFACE CONDUCTIVITY (S) ----- 0.01500 MOH/METER
 SURFACE REFRACTIVITY (NS) ----- 321.00 N-UNITS
 SUM OF ELEVATION ANGLES (TE) ----- 3.08365 RADIANS
 DISTANCE BETWEEN ANTENNAS (DIST) ----- 80.00 K-METERS
 ATTENUATION BELOW FREE SPACE (AE) ----- 43.57 DB
 INTERDECILE RANGE OF TERRAIN HEIGHT (DH) ----- 580.00 METERS
 SUM OF SMOOTH-EARTH HORIZON DISTANCES (CLS) ----- 19.44 K-METERS
 DIFFRACTION ATTENUATION AT DISTANCE DLS (ALS) ----- 54.71 DB
 PERMITTIVITY OR RELATIVE DIELECTRIC CONSTANT (E) ----- 20.00
 ESTIMATED SCATTER ATTENUATION BELOW FREE SPACE (AES) ----- 95.45 DB
 STRUCTURAL RECEIVER ANTENNA HEIGHT ABOVE GROUND (H2G) ----- 3.00 METERS
 STRUCTURAL TRANSMITTER ANTENNA HEIGHT ABOVE GROUND (H1G) ----- 4.00 METERS
 ESTIMATED DIFFRACTION ATTENUATION BELOW FREE SPACE (AEC) ----- 45.55 DB
 COEFFICIENT THAT DEFINES SLOPE OF A SMOOTH CURVE OF ACR (K1) ----- 0.51568 DB/KM
 COEFFICIENT THAT DEFINES SLOPE OF A SMOOTH CURVE OF ACR (K2) ----- 0.86623 DB/KM
 SLOPE OF THE CURVE OF SCATTER ATTENUATION AS VERSUS DISTANCE (MS) ----- 0.04735 DB/KM
 DISTANCE WHERE DIFFRACTION AND SCATTER ATTENUATIONS ARE EQUAL (DX) ----- 230.35 K-METERS
 ATTENUATION WHERE DIFFRACTION AND SCATTER ATTENUATION ARE EQUAL (ADX) ----- 106.35 DB
 SLOPE OF THE CURVE OF DIFFRACTION ATTENUATION AS VERSUS DISTANCE (MD) ----- 0.24484 DB/KM

--- SIGNAL STRENGTH DATA INPUT ---

TRANSMITTER POWER OUT ----- 100.00 WATTS
 TRANSMITTER TRANSMISSION LINE LOSS ----- 2.00 DB
 TRANSMITTER ANTENNA GAIN ----- 10.00 DB
 RECEIVER SENSITIVITY ----- -90.00 DBM
 RECEIVER TRANSMISSION LINE LOSS ----- 2.00 DB
 RECEIVER ANTENNA GAIN ----- 10.00 DB

FIRST DATA CARD

```

COLUMN: 01-10 "TYPE OF TERRAIN" -INTEGER (RIGHT JUSTIFIED)
CODE: 1 ---"COLORADO PLAINS" (OMIT THIRD DATA CARD)
      2 ---"COLORADO MOUNTAINS" (OMIT THIRD DATA CARD)
      3 ---"OHIO" (OMIT THIRD DATA CARD)
      4 ---"USER TERRAIN DATA" WITHOUT DATA SUPPRESSION
      5 ---"USER TERRAIN DATA" NO "OUTPUT PARAMETERS"
          PRINTED
COLUMN: 11-20 "DB LOSS"
CODE: 0 N3 DB DATA DESIRED (OMIT SECOND DATA CARD)
CODE: 1 DB DATA DESIRED (MUST INCLUDE SECOND DATA CARD)
COLUMN: 21-30 "DISTANCE BETWEEN ANTENNAS" (1-2,000) K-METERS
          -REAL

```

```

19 READ (5,20,END=9999) ITERR, IDB, DIST
20 FORMAT (2I10,F10.5)

```

SECOND DATA CARD (USED FOR SIGNAL STRENGTH DB DATA CUT)

```

COLUMN: 01-10 "TX POWER OUT" (WATTS) -REAL(+) POSITIVE NUMBER
COLUMN: 11-20 "TX ANTENNA GAIN" (DB) -REAL(+)
COLUMN: 21-30 "RX ANTENNA GAIN" (DB) -REAL(+)
COLUMN: 31-40 "TRANSMISSION LINE LOSS" (DB) -REAL(+)
COLUMN: 41-50 "RECEIVER LINE LOSS" (DB) -REAL(+)
COLUMN: 51-60 "RECEIVER INPUT LEVEL" (DBM) -REAL(+)

```

```

25 IF (IDB.NE.1) GO TO 24
READ (5,23) TXPO, TXAG, RXAG, TRLL, RXLL, RXIN
23 FORMAT (6F10.2)
DDB=10*(DLOG10(TXPO)+TXAG+RXAG-TRLL-RXLL)

```

THIRD DATA CARD

```

COLUMN: 01-10 "SURFACE REFRACTIVITY" (250-400 N-UNITS)-INTEGER
          (RIGHT JUSTIFIED)
COLUMN: 11-20 "SURFACE CONDUCTIVITY" MHO/METER -REAL
COLUMN: 21-30 "PERMITTIVITY OR RELATIVE DIELECTRIC CONSTANT"
          -REAL
COLUMN: 31-40 "INTERDECILE RANGE" DELTA-H -REAL

```



```

C C C
24 IF (ITERR.LT.4) GO TO 26
21 READ (5,21) NSS,SS,EE,DHH
   FORMAT (110,3F10.5)

FOURTH DATA CARD
      COLUMN: 01-10 "ANTENNA POLARIZATION" -REAL
      CODE: +1.00 VERTICAL POLARIZATION
      CODE: -1.00 HORIZONTAL POLARIZATION
      COLUMN: 11-20 "FREQUENCY" MEGAHERTZ (20-40,000) -REAL
      COLUMN: 21-30 "STRUCTURAL ANTENNA HEIGHT OF TRANSMITTING
      METERS -REAL
      COLUMN: 31-40 "ANTENNA" (0.5-3000.0) METERS -REAL
      COLUMN: 31-40 "STRUCTURAL ANTENNA HEIGHT OF RECEIVER ANTENNA"
      (0.5-3000.0) METERS -REAL

26 READ (5,22) POL,F,H1G,H2G
22 FORMAT (4F10.5)

COLCRADO PLAINS TERRAIN DATA

NS=290.
S=.005
E=15.
DH=90.
DHS=90.
IF (ITERR.EQ.2) GO TO 3
IF (ITERR.EQ.3) GO TO 5
IF (ITERR.GT.3.AND.ITERR.LT.6) GO TO 7

WRITE OUT COLORADO PLAINS TERRAIN HEADING

WRITE (6,2)
2 FORMAT ('1',////////,54X,'--- COLORADO PLAINS ---',/)
GO TO 9

COLORADC MOUTAIN TERRAIN DATA
C C C

```


CC	3	DH=650. DHS=650.	JMC	144
CCCCC			JMC	145
			JMC	146
			JMC	147
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			JMC	190
			JMC	191


```

WRITE (6,4)
FORMAT ('1',////////,53X,'---- COLORADO MOUNTAINS ----',/)
GO TO 9

OHIO TERRAIN DATA

5 NS=312.

WRITE OUT OHIO TERRAIN HEADING

WRITE (6,6)
FORMAT ('1',////////,60X,'---- OHIO ----',/)
GO TO 9

USER TERRAIN DATA

7 NS=NS
S=SS
E=EE
DH=DHH
DHS=DHH

WRITE OUT USER TERRAIN HEADING

WRITE (6,8)
FORMAT ('1',////////,53X,'---- USER TERRAIN DATA ----',/)
GO TO 9

WRITE OUT SIGNAL FREQUENCY

```



```

CALL LOS
STORE ATTENUATION (ACR) AND DISTANCE (D) DATA
SD(IDIS)=D
ACT=ACR+32.45+20*DLOG10(F)+20*DLOG10(D)
SA(IDIS)=ACT
GO TO 300

CALL SUBROUTINE "DIFF"

CALL DIFF
SD(IDIS)=D
ACT=ACR+32.45+20*DLOG10(F)+20*DLOG10(D)
SA(IDIS)=ACT
AE=AOG-K1*D0-K2*DLOG10(D0)
ADX=AE+MD*DX
IF(-RXIN.LT.DDB-ACT+30.0) DMAX=D

END OF "100 POINT DISTANCE" LOOP

300 DB(IDIS)=DDB-ACT+30.0

WRITE "DISTANCE, TRANS-LOSS" HEADING AND DATA.

WRITE (6,301)
FORMAT(1X,5(3X,'DISTANCE',2X,'TRANS-LOSS ',2X))
WRITE(6,301)
FORMAT(5(6X,'(KM)',7X,'(DB)',5X),///)
DO 303 K=1,20
WRITE(6,302) (SD(K+20*(N-1)),SA(K+20*(N-1)),N=1,5)
FORMAT(2X,5(F8.4,'-----',F6.2,6X),/)
CONTINUE

SCALE GRAPH FOR ATTENUATION.

SCAL=0.0

```

JMC 240
JMC 241
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JMC 286
JMC 287

CCCCC

```

308 WRITE OUTPUT PARAMETERS JMC
337 IF(ITERR.EQ.5) GO TO 69 JMC
338 WRITE(6,74) JMC
339 FORMAT(1,52X,'---- PROGRAM PARAMETERS ---',///) JMC
340 IF(POL.GT.0.0) GO TO 61 JMC
341 WRITE(6,60) JMC
342 FORMAT(//,15X,'POLARIZATION (POL) -----',///) JMC
343 GO TO 63 JMC
344 WRITE(6,62) JMC
345 FORMAT(//,15X,'POLARIZATION (POL) -----',///) JMC
346 GO TO 63 JMC
347 WRITE(6,62) JMC
348 FORMAT(//,15X,'POLARIZATION (POL) -----',///) JMC
349 WRITE(6,64) F,S,NS,TE,DIST,AE,DH,DLS,ALS JMC
350 FORMAT(15X,'FREQUENCY OF SIGNAL (F) -----',///) JMC
351 'SURFACE CONDUCTIVITY (S) MEG-HERTZ',///, JMC
352 'SURFACE REFRACTIVITY (NS) MHO/METER',///, JMC
353 'SUM OF ELEVATION ANGLES (TE) N-UNITS',///, JMC
354 'DISTANCE BETWEEN ANTENNAS (DIST) RADIANS',///, JMC
355 'ATTENUATION BELOW FREE SPACE (AE) K-METERS',///, JMC
356 'INTERDECIBLE RANGE OF TERRAIN HEIGHT (DH) DB',///, JMC
357 'SUM OF SMOOTH-EARTH HORIZON DISTANCES (DLS) METERS',///, JMC
358 'DIFFRACTION ATTENUATION AT DISTANCE DLS (ALS) K-METERS',///, JMC
359 WRITE(6,65) E,AES,H2G,H1G,AED,K1,K2,MS JMC
360 FORMAT(15X,'PERMITTIVITY OR RELATIVE DIELECTRIC CONSTANT (E) ---',///) JMC
361 'ESTIMATED SCATTER ATTENUATION BELOW FREE SPACE (AES) DB',///, JMC
362 'STRUCTURAL RECEIVER ANTENNA HEIGHT ABOVE GROUND (H2) DB',///, JMC
363 'STRUCTURAL TRANSMITTER ANTENNA HEIGHT ABOVE GROUND (H1) DB',///, JMC
364 'ESTIMATED DIFFRACTION ATTENUATION BELOW FREE SPACE (AED) DB',///, JMC
365 'COEFFICIENT THAT DEFINES SLOPE OF A SMOOTH CURVE OF DB/KM',///, JMC
366 ACR (K1) -----,F7.5, DB/KM,///, JMC
367 JMC
368 JMC
369 JMC
370 JMC
371 JMC
372 JMC
373 JMC
374 JMC
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382 JMC
383 JMC

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*15X, 'COEFFICIENT THAT DEFINES SLOPE OF A SMOOTH CURVE OF JMC 384
*ACR (K2) -----,F7.5, DB/KM JMC 385
*15X, 'SLOPE OF THE CURVE OF SCATTER ATTENUATION AS VERSUS JMC 386
*DISTANCE (MS) -----,F7.5, DB/KM JMC 387
*WRITE(6,66) DX,ADX,MD JMC 388
*FORMAT(15X, (DX) -----,F7.2, K-METERS, JMC 389
*CN ARE EQUAL (DX) -----,F7.2, SCATTER ATTENUATION JMC 390
*CN ARE EQUAL (ADX) -----,F7.2, SCATTER ATTENUATION JMC 391
*CN ARE EQUAL (MD) -----,F7.2, SCATTER ATTENUATION JMC 392
*15X, 'SLOPE OF THE CURVE OF DIFFRACTION ATTENUATION AS VE JMC 393
*RSUS, DISTANCE (MD) -----,F7.5, DB/KM JMC 394
*IF (IDB.NE.1) GO TO 69 JMC 395
*WRITE(6,68) TXPG,TRLL, TXAG, RXGG, RXLL, RXAG JMC 396
*FORMAT(15X, (TXPG,TRLL, TXAG, RXGG, RXLL, RXAG) -----, JMC 397
*15X, 'TRANSMITTER POWER OUT -----, F7.2, WATTS JMC 398
*15X, 'TRANSMITTER TRANSMISSION LINE LOSS -----, F7.2, DB JMC 399
*15X, 'TRANSMITTER ANTENNA GAIN -----, F7.2, DB JMC 400
*15X, 'RECEIVER SENSITIVITY -----, F7.2, DB JMC 401
*15X, 'RECEIVER TRANSMISSION LINE LOSS -----, F7.2, DB JMC 402
*15X, 'RECEIVER ANTENNA GAIN -----, F7.2, DB JMC 403
*15X, 'RECEIVER TRANSMISSION LINE LOSS -----, F7.2, DB JMC 404
*15X, 'RECEIVER ANTENNA GAIN -----, F7.2, DB JMC 405
*15X, 'RECEIVER TRANSMISSION LINE LOSS -----, F7.2, DB JMC 406
*15X, 'RECEIVER ANTENNA GAIN -----, F7.2, DB JMC 407
*15X, 'RECEIVER TRANSMISSION LINE LOSS -----, F7.2, DB JMC 408
*15X, 'RECEIVER ANTENNA GAIN -----, F7.2, DB JMC 409
*15X, 'RECEIVER TRANSMISSION LINE LOSS -----, F7.2, DB JMC 410
*15X, 'RECEIVER ANTENNA GAIN -----, F7.2, DB JMC 411
*15X, 'RECEIVER TRANSMISSION LINE LOSS -----, F7.2, DB JMC 412
*15X, 'RECEIVER ANTENNA GAIN -----, F7.2, DB JMC 413
*15X, 'RECEIVER TRANSMISSION LINE LOSS -----, F7.2, DB JMC 414
*15X, 'RECEIVER ANTENNA GAIN -----, F7.2, DB JMC 415
*15X, 'RECEIVER TRANSMISSION LINE LOSS -----, F7.2, DB JMC 416
*15X, 'RECEIVER ANTENNA GAIN -----, F7.2, DB JMC 417
*15X, 'RECEIVER TRANSMISSION LINE LOSS -----, F7.2, DB JMC 418
*15X, 'RECEIVER ANTENNA GAIN -----, F7.2, DB JMC 419

66 69 CONTINUE JMC 420
67 START PROGRAM AGAIN JMC 421
68 GC TO 19 JMC 422
9999 CONTINUE JMC 423
STOP JMC 424
END JMC 425
SUBROUTINE DIFF JMC 426
SUBROUTINE TO COMPUTE DIFFRACTION ATTENUATION JMC 427
IMPLICIT REAL*8(A-H,O-Z) JMC 428
COMMON /NR/W,SW3,SW4,SA3,SA4,SAFO,JZ JMC 429
COMMON /MAR14/D3,D4,T5
COMMON /MM/F,D,NS,A,DH,DHS,S,E,PCL,KM
COMMON /MP/H1E,H2E,H1G,H2G,DLS1,DLS2,DL1,DL2,DL,DLS,TE1,TE2,TE,KLJMC
COMMON /MLDS/ AG,AD,AS,ACR,AED,MD,AH50,AH5,D5,MS,AES,DX,H5 JMC

```



```

X2=B2*D/L2/A2*.6666666666
X3=B3*(D3-DL)/A3*.6666666666+X1+X2
X4=B4*(D4-DL)/A4*.6666666666+X1+X2
XL1=450./DABS(DLOG10(K1)*3)
XL2=450./DABS(DLOG10(K2)*3)
IF(X1.GT.0...AND.X1.LE.200. .AND.K1.GE.0..AND.K1.LE..00001)
  C GO TO 16
16 GO TO 17
  T=40.*DLOG10(X1)-117.
  T1=-117.
  T2=DMINI((DABS(T)),(DABS(T1)))
  FX1=T
  IF(T2.EQ.DABS(T1)) FX1=T1
  IF(X2.GT.0...AND.X2.LE.200. .AND.K2.GE.0..AND.K2.LE..00001)
    C GO TO 18
18 GO TO 19
  T=40.*DLOG10(X2)-117.
  T1=-117.
  T2=DMINI((DABS(T)),(DABS(T1)))
  FX2=T
  IF(T2.EQ.DABS(T1)) FX2=T1
  IF(X1.GT.0...AND.X1.LE.200. .AND.K1.GT..00001 .AND.K1.LT.1.
    C GO TO 21
19 GO TO 22
  FX1=40.*DLOG10(X1)-117.
  IF(X1.LE.XL1) FX1=20.*DLOG10(K1)+2.5*1. E-5*X1/K1-15.
  IF(X2.GT.0...AND.X2.LE.200. .AND.K2.GT..00001 .AND.K2.LT.1.
    C GO TO 23
20 GO TO 24
  FX2=40.*DLOG10(X2)-117.
  IF(X2.LE.XL2) FX2=20.*DLOG10(K2)+2.5*1. E-5*X2/K2-15.
  W1=.0134*X1*DEXP(-.005*X1)
  W2=.0134*X2*DEXP(-.005*X2)
  IF(X1.GT.200..AND.X1.LE.2000.)
    C FX1=W1*(40.*DLOG10(X1)-117.)+(1.-W1)*(.05751*X1-10.*DLOG10(X1))
  IF(X1.GT.200..AND.X2.LE.2000.)
    C FX2=W2*(40.*DLOG10(X2)-117.)+(1.-W2)*(.05751*X2-10.*DLOG10(X2))
  IF(X1.GT.2000.) FX1=.05751*X1-10.*DLOG10(X1)
  IF(X2.GT.2000.) FX2=.05751*X2-10.*DLOG10(X2)
  GX3=.05751*X3-10.*DLOG10(X3)
  GX4=.05751*X4-10.*DLOG10(X4)
  AR3=GX3-FX1-FX2-20.
  AR4=GX4-FX1-FX2-20.
  C
  C COMBINATION OF ROUNDED EARTH AND KNIFE EDGE DIFFRACTION
28 DHD3=DH*(1.-.8*DEXP(-.02*D3))
  DHD4=DH*(1.-.8*DEXP(-.02*D4))

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JMC	573


```

AXO=ADC+MDO;DXO
ASX=AXO+(AH5-AH50)
AES=ASX-MS;DXO
AS=AES+MS;D
30 DX=(AES-AED)/(MD-MS) 3333333333;DLOG10(F)
IF(DXN.GT.DX) AES=AED+(MD-MS);DXN
IF(DXN.GT.DX) AS=AES+MS;D
IF(DXN.GT.DX) DX=DXN
ACR=AD
IF(D.GT.DX) ACR=AS
DL1=SDL1
DL2=SDL2
CL=SDL
TE1=STE1
TE2=STE2
TE=STE
CH=DHS
41 CONTINUE
40 RETURN
END

```

JMC 574
JMC 575
JMC 576
JMC 577
JMC 578
JMC 579
JMC 580
JMC 581
JMC 582
JMC 583
JMC 584
JMC 585
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JMC 588
JMC 589
JMC 590
JMC 591
JMC 592
JMC 593
JMC 594

```

SUBROUTINE SCATT
SUBROUTINE TO COMPUTE SCATTER PARAMETERS
IMPLICIT REAL*8(A-H,O-Z)
COMMON /MM/F,D,NS,A,CH,DHS,S,E,POL,KM
COMMON /MP/H1E,H2E,H1G,H2G,CLS1,DLS2,DL1,DL2,DL,DLS,TE1,TE2,TE,KL
COMMON /MAR14/D3,D4,T5
COMMON /MLDS/AG,AD,AS,ACR,AED,MD,AH50,AH5,C5,MS,AFS,DX,H5
REAL*8 NS,MD,MDO,MS,MSS,MDS,K1,K2,K3,K4
KK=0
10 KK=KK+1
D5=DL+200.
D6=DL+400.
T5=TE+D5/A
T6=TE+D6/A
H5=DMIN1((1./H1E+1./H2E)/(T5;F;DABS(.007-.058;T5))), (15.0D0))
H6=DMIN1((1./H1E+1./H2E)/(T6;F;DABS(.007-.058;T6))), (15.0D0))
S5=H5+10.;DLOG10(F;T5;4)-.1;(NS-301.);DEXP(-T5;D5/40.)
S6=H5+10.;DLOG10(F;T6;4)-.1;(NS-301.);DEXP(-T6;D6/40.)
IF(T5;D5.LT.10.) AH5=S5+103.4+.332;T5;D5-10.;DLOG10(T5;D5)
IF(T6;D6.LT.10.) AH6=S6+103.4+.332;T6;D6-10.;DLOG10(T6;D6)
IF(T5;D5.GT.10.) .AND.T5;D5.LE.70.) AH5=S5+97.1+.212;T5;D5-2.5;
CDLOG10(T5;D5)
IF(T6;D6.GT.10.) .AND.T6;D6.LE.70.) AH6=S6+97.1+.212;T6;D6-2.5;

```

JMC 595
JMC 596
JMC 597
JMC 598
JMC 599
JMC 600
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JMC 617
JMC 618
JMC 619

C C C


```

CDLOG10(T6*D6)
IF(T5*D5 .GT. 70.) AH5=S5+86.8+.157*T5*D5+5.*DLOG10(T5*D5)
IF(T6*D6 .GT. 70.) AH6=S6+86.8+.157*T6*D6+5.*DLOG10(T6*D6)
MS=(AH6-AH5)/(D6-D5)
IF (KK .EQ. 2) GO TO 25
IF (H5 .LE. 10.) GO TO 30
IF (KK .EQ. 1) GO TO 20
25 MS=MSS
AH50=AH5
AH5=AH5S
D5=D5S
GO TO 30
20 DH=0.
DL1=DL1*DEXP(-.07*DSQRT(DH/DMAX1(5.0D0,H1E)))
DL2=DL2*DEXP(-.07*DSQRT(DH/DMAX1(5.0D0,H2E)))
DL=DL1+DL2
TE1=((0.00065/DLS1)*((DLS1/DL1-1)*DH-3.077*H1E)
TE2=((0.00065/DLS2)*((DLS2/DL2-1)*DH-3.077*H2E)
TE=DMAX1((TE1+TE2),(-DL/A))
T=TE+D/A
AH5S=AH5
MSS=MS
D5S=D5
GO TO 10
30 CONTINUE
RETURN
END

```

```

SUBROUTINE LOS
SUBROUTINE TO COMPUTE LINE OF SIGHT ATTENUATION
IMPLICIT REAL*8(A-H,O-Z)
COMMON /MM/F,D,NS,A,DH,DHS,S,E,POL,KM
COMMON /NR/W,SW3,SW4,SA3,SA4,SAF0,JZ
COMMON /MP/H1E,H2E,H1G,H2G,DLS1,DLS2,DL1,DL2,DL,DLS,TE1,TE2,TE,KL
COMMON /MLDS/AG,AD,AS,ACR,AED,MD,AH50,AH5,D5,MS,AES,DX,H5
COMMON /ML/DO,D1,D01,D02,A0,A1,K1,K2,AL,ALS,AOG
REAL*8 NS,MD,MDD,MS,MSS,MDS,K1,K2,K3,K4,M
KM=2
CALL DIFF
KM=0
CALCULATION OF TWO RAY THEORY
D01=.00004*H1E*H2E*F

```



```

D02=DMIN1((-AED/MD),(DL-2.))
IF (AED .GE. 0.) D0=DMIN1(D01,(.5*DL))
IF (AED .LT. 0.) D0=.5*DL
IF (AED .LT. 0.) AND. D02 .GE. D0) D0=D02
D1=D0+.25*(DL-D0)
IF (D01 .LE. D0) D1=D0+.25*(DLS-D0)
J=0
DS=D
IF (J .EQ. 0) D=D0
22 DIV=1
PSI=DATAN((H1E+H2E)/(1000.*D))
2 DHD=DH*(1-.8*DEXP(-.02*D))
SH=.78*DHD*DEXP(-.5*DHD*.25)
SP=DSIN(PSI)
X=18000.*S/F
P2=(DSQRT((E-DCOS(PSI))*2.*X*X)+E-DCOS(PSI))*DCOS(PSI))/JMC
C2=.DSQRT(P2)
P=X/(2.*P)
IF (POL .EQ. 1.) B=(E+E*X*X)/(P2+Q*Q)
IF (POL .EQ. -1.) B=1./(P2+Q*Q)
IF (POL .EQ. 1.) M=2.*(P+E+Q*X)/(P2+Q*Q)
IF (POL .EQ. -1.) M=2.*P/(P2+Q*Q)
R2=(1.+B*SP*SP-M*SP)/(1.+B*SP*SP+M*SP)
RE=DSQRT(SP)
SQEXF=DSQRT(R2)*DEXP(-.0209584473*F*SH*SP)*DIV
IF (SQEXF .GT. .5 .AND. SQEXF .GT. RE) RE=SQEXF
C=DATAN(Q/(P+SP))-DATAN(Q/(P-SP))
IF (POL .EQ. -1.) GO TO 40
Y1=(X*SP+Q)/(E*SP+P)
Y2=(X*SP-Q)/(E*SP-P)
IF (E*SP .GE. P) C=DATAN(Y1)-DATAN(Y2)+3.141592654
IF (E*SP .LT. P .AND. P*SP .GT. .5) C=DATAN(Y1)+DATAN(Y2)
IF (E*SP .LT. P .AND. P*SP .LE. .5) C=DATAN(Y1)-DATAN(Y2)
40 IF (J .EQ. 0)
CAO=-10.*DLOG10(1.+RE*RE-2.*RE*DCOS(.000041917*F*H1E*H2E/D0-C))
IF (J .EQ. 1) GO TO 3
D=D1
J=1
GO TO 22
3 CONTINUE
D=DS
IF (J .EQ. 1)
CA1=-10.*DLOG10(1.+RE*RE-2.*RE*DCOS(.000041917*F*H1E*H2E/D1-C))
C COMBINATION OF TWO RAY THEORY AND DIFFRACTICN
ALS=AED+MD*DLS

```



```

AL=AED+MD*DL
DEDO=AED+MD*D0
DEDI=AED+MD*D1
SAO=A0
SAI=A1
W=1./((1.+F*DH*.0001)
AO=DMIN1((W*A0+(1.-W)*DEDO),DEDO)
AI=DMIN1((W*AI+(1.-W)*DEDI),DEDI)
10 K2=((ALS-A0)*(D1-D0)-(AI-A0)*(DLS-D0))/((D1-D0)*DLOG10(DLS/D0))-
C(DLS-D0)*DLOG10(D1/D0)
K2=DMAX1(K2,0.0D0)
K1=((ALS-A0)-K2*DLOG10(DLS/D0))/(DLS-D0)
IF (K1 .GT. 0.) GO TO 50
K1=0.
K2=(ALS-A0)/(DLOG10(DLS/D0))
50 AG=A0+K1*(D-D0)+K2*DLOG10(D/D0)
IF (AG .LT. 0.) AG=0.
51 AOG=A0
53 ACR=AG
RETURN
END

```

JMC 714
JMC 715
JMC 716
JMC 717
JMC 718
JMC 719
JMC 720
JMC 721
JMC 722
JMC 723
JMC 724
JMC 725
JMC 726
JMC 727
JMC 728
JMC 729
JMC 730
JMC 731
JMC 732
JMC 733
JMC 734

```

SUBROUTINE UTPLJT (X, Y, NDATA, XMAX, XMIN, YMAX, YMIN, KKZ, MODCUR)
DIMENSION GRID(61,81), XSCALE(5), YSCALE(7)
DIMENSION X (1), Y (1)
INTEGER*2 GRID, BLANK, DOT, XCHAR(4)/1H., 1H+, 1H*, 1HX/
DATA DOT, BLANK/Z4B40, Z4040/
KDATA=NDATA*KKZ
IF(MODCUR.GT.1) GO TO 444

```

JMC 735
JMC 736
JMC 737
JMC 738
JMC 739
JMC 740
JMC 741
JMC 742
JMC 743
JMC 744
JMC 745
JMC 746
JMC 747
JMC 748
JMC 749
JMC 750
JMC 751
JMC 752
JMC 753
JMC 754
JMC 755
JMC 756
JMC 757
JMC 758
JMC 759

```

GRID IS THE MATRIX USED TO PLJT THE POINTS
IERR=0
CHECKING X AND Y POINTS AND PLOTTING THOSE OUT OF RANGE
AT THE MARGIN
DO 30 I=1, KDATA, KKZ
IF(X(I).GT.XMAX.OR.X(I).LT.XMIN.OR.Y(I).GT.YMAX.OR.Y(I).LT.YMIN)
1 IERR=IERR+1
IF(X(I).LE.XMAX) GO TO 205
X (I)=XMAX
GOTO 210
205 IF(X(I).GE.XMIN) GO TO 210
X (I)=XMIN
210 IF(Y(I).LE.YMAX) GO TO 215
Y (I)=YMAX

```

C C C C C


```

C      GOTO 30
215 IF(Y(I).GE.YMIN) GO TO 30
   Y (I)=YMIN
C
C      30 CONTINUE
C
C      PLOTTING X AND Y AXIS , IF NECESSARY
C
C      JERR=0
C      X RANGE=XMAX-XMIN
C      Y RANGE=YMAX-YMIN
C      IF (Y RANGE.NE.0.) GO TO 298
C      IF (YMIN.EQ.0.) GO TO 889
C      YMIN=0.
C      Y RANGE=YMAX
C      GO TO 299
298 IF (X RANGE.NE.0.) GO TO 299
   IF (XMIN.EQ.0.) GO TO 887
   XMIN=0.
   X RANGE=XMAX
C
C      BLANKING OUT MATRIX-(GRID)
C
C      DO 300 I=1,61
C      DO 301 JJ=1,81
C      GRID(I,JJ)=BLANK
301 CONTINUE
300 IF(XMAX<XMIN-GE.0.) GO TO 222
   IYAXIS=80./(-XMIN)/X RANGE+1.5
   DO 40 I=1,61
40 GRID(I,IYAXIS)=DOT
222 IF(YMAX<YMIN-GE.0.) GO TO 333
   IXAXIS=60./YMAX/Y RANGE+1.5
   DO 60 I=1,81
60 GRID(IXAXIS,I)=DOT
C
C      CCMPUTE PROPER SCALE NUMBERS
C
C      333 XINCR=X RANGE/4.
C      YINCR=Y RANGE/6.
C      XSCALE(1)=XMAX
C      XSCALE(5)=XMIN
C      DO 80 I=2,4
80 XSCALE(I)=XSCALE(I-1)-XINCR
   IF(ABS(XSCALE(I)).LT.1.E-4) XSCALE(I)=0.
   CONTINUE
   YSCALE(1)=YMAX
   YSCALE(7)=YMIN
C

```



```

92 WRITE(6,19) (GRID(IK,IX),IX=1,81)
19 FORMAT(15X,' ',81A1,' ')
101 CONTINUE
    IF (AXR.LT.1.E+8.AND.AXR.GE..95) GO TO 402
    WRITE(6,22) XSCALE
    FCFORMAT(15X,' ',8(' '+FCFORMAT(10X,1PE10.3,4(10X,F10.3),//))
22 GO TO 403
402 WRITE(6,217) XSCALE
217 FORMAT(15X,' ',8(' '+FCFORMAT(10X,1PE10.3,4(10X,F11.2),//))
403 IF (IERR.GT.0) WRITE(6,20).IERR
20 FORMAT(10X,'NUMBER OF POINTS OUT OF RANGE = ',I4)
1000 RETURN
C
889 WRITE(6,888)
888 FORMAT(' ALL Y VALUES=0. CANNOT SETUP PLOT GRID. CHECK MAX & MIN
1 WHEN MODCUR=0 OR 1.')
JERR=10
RETURN
887 WRITE(6,886)
886 FORMAT(' ALL X VALUES=0. CANNOT SETUP PLOT GRID. CHECK MAX & MIN
1 WHEN MODCUR=0 OR 1.')
JERR=10
RETURN
885 WRITE(6,884)
884 FORMAT(' GRID NOT SETUP WHEN MODCUR LAST 0 OR 1. NO PLOT UNTIL GRID
1D PROPERLY SETUP.')
RETURN
END

FUNCTION FNA(C)
IMPLICIT REAL*8(A-H,O-Z)
FNA=6.02+9.11*(C-1.27)*C
RETURN
END

FUNCTION FNB(C)
IMPLICIT REAL*8(A-H,O-Z)
FNB=12.953+20.*DLOG10(C)
RETURN
END

```

JMC 856
JMC 857
JMC 858
JMC 859
JMC 860
JMC 861
JMC 862
JMC 863
JMC 864
JMC 865
JMC 866
JMC 867
JMC 868
JMC 869
JMC 870
JMC 871
JMC 872
JMC 873
JMC 874
JMC 875
JMC 876
JMC 877
JMC 878
JMC 879
JMC 880
JMC 881
JMC 882
JMC 883

JMC 884
JMC 885
JMC 886
JMC 887
JMC 888

JMC 889
JMC 890
JMC 891
JMC 892
JMC 893


```

FUNCTION FNC(C,F)
IMPLICIT REAL*8(A-H,O-Z)
FNC=416.4*F*.3333333333*(1.607-C)
RETURN
END

```

JMC 894
JMC 895
JMC 896
JMC 897
JMC 898

```

FUNCTION FND(C,F,E,X)
IMPLICIT REAL*8(A-H,O-Z)
FND=(.36278/(C*F)*.3333333333)*1./((E-1.)*E*2.+X*X)*E*.25
RETURN
END

```

JMC 899
JMC 900
JMC 901
JMC 902
JMC 903

```

FUNCTION FNE(C,E,X)
IMPLICIT REAL*8(A-H,O-Z)
FNE=C*DSQRT(E+E*X*X)
RETURN
END

```

JMC 904
JMC 905
JMC 906
JMC 907
JMC 908

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(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) Naval Postgraduate School Monterey, California		2a. REPORT SECURITY CLASSIFICATION Unclassified	
		2b. GROUP	
3. REPORT TITLE "TROPOPLOT" A Highly Accurate Long Range Computer Program to do Predictions of Tropospheric Radio Transmission Loss Over Irregular Terrain.			
4. DESCRIPTIVE NOTES (Type of report and, inclusive dates) Master's Thesis: June 1973			
5. AUTHOR(S) (First name, middle initial, last name) James M. Callaghan			
6. REPORT DATE June 1973		7a. TOTAL NO. OF PAGES 45	7b. NO. OF REFS 2
8a. CONTRACT OR GRANT NO.		9a. ORIGINATOR'S REPORT NUMBER(S)	
b. PROJECT NO.			
c.		9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)	
d.			
10. DISTRIBUTION STATEMENT Approved for public release; distribution unlimited.			
11. SUPPLEMENTARY NOTES		12. SPONSORING MILITARY ACTIVITY Naval Postgraduate School Monterey, California 93940	
13. ABSTRACT The object of this study was to develop a highly accurate long range computer program to do predictions of tropospheric radio transmission loss over irregular terrain. The computer program was to be easy to use with an input and output data format such that the user could use the program with little prior instruction. Signal strength calculation capability was also to be included in the program. The basis for the program theory was ESSA Research Report number ERL 67-ITS 67, "Prediction of Tropospheric Radio Transmission Loss Over Irregular Terrain."			

KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Prediction of Long-Term Median Tropospheric Radio Transmission Loss Over Irregular Terrain						
Tropospheric Scatter						
Tropospheric Diffraction						
Knife Edge Diffraction						
Short and Long Term Fading						
Tropospheric Communications Systems						

Thesis

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143483

"TROPOPLOT"; an improved Fortran program for prediction of long-term median tropospheric radio transmission loss over irregular terrain.

Thesis

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"TROPOPLOT"; an improved Fortran program for prediction of long-term median tropospheric radio transmission loss over irregular terrain.

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